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Optical lattice clocks with Sr atoms

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The Idea of using cold atoms confined in an optical lattice for an optical clock was proposed by H. Katori at the sixth symposium on frequency standards and metrology. Since then, this idea became an experimental reality. We review here the contribution of LNE-SYRTE to these developments.

A first point is a study of the depth of the required lattice depth to cancel motional effects in such a clock. We show that a relatively small lattice depth (about 10 recoil energies) is sufficient provided the lattice is oriented vertically. In that case gravity lifts the degeneracy between adjacent potential wells which strongly inhibits tunnelling induced motion and reduces the associated frequency shift and line broadening. In turn, offering the possibility to operate the lattice at small lattice depths both minimizes the requirements in terms of lattice induced shift rejection and opens the possibility to operate lattice clocks with atoms of small polarizability like Hg.

A second point is the study of the atomic hyperpolarizability which leads to a frequency shift proportional to the square of the lattice depth. We show that for Sr this effect is small enough to not jeopardize the feasibility of a high accuracy optical lattice clock.

In a third point, we present recent experimental developments. We demonstrate an accurate frequency measurement of the Sr clock transition with accuracy in the low 10^{-15} range. We describe a new non-destructive method to detect the atoms and discuss the associated gain in terms of frequency stability. Finally, we report on the progress towards the comparison of two independent Sr lattice clocks.